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Research on Intelligent Fault Location for Multistage in Large-scale Distributed Measurement Environment

Rong Ding[a,b], Xiaoguang Li[a,b], Tongyu Zhu[a,b], Zhenhan Zhong[a,b], Jufu Zhang[a,b]a

[a]*State Key Laboratory of Software Development Environment, Beihang University,*
[b]*School of Computer Science and Engineering, Beihang University,*
Beijing 100191, China

Abstract

Based on the analysis of fault location methods, this paper brings presents an intelligent method on the basis of classification in large-scale measurement system. Three independent functional units, which are data acquisition unit (DAU), data transmission unit (DTU) and terminal computer (TC), are defined in distributed environment. And then, a fault localization method corresponding to all levels are proposed in detail. Finally we conduct experiments on our experimental platform, and results show that our approach can accurately and quickly achieve the mission of fault location in large-scale distributed measurement system.

Keywords: Large-scale Distributed Measurement Environment; System Classification; Intelligent Fault Location; Multistage

1. Introduction

With the development of modern science and technology, measurement tasks are getting more and more complex. Traditional centralized measurement system cannot satisfy the requirements which are complex, long-distance, large-scale and the like in the measurement environment that includes not only using numerous instruments like plug-in cards, chassis, cabling, but becoming geographically larger as well. On account of complex and long-distance measurement, faults are becoming more difficult and serious to diagnose and locate with traditional centralized measurement system [1]. However, the conditions are provided by the improvement of computing capabilities and software environment, and thus distributed system of measurement has emerged as the times require [2].

However, distributed measurement system (DMS) is not omnipotent to solve all problems in complex large-scale measurement. The requirement for real time in data communication will be limited in DMS when the number of measured points is large and the measurement metrics are various [3], [4]. DMS also has troubles in the aspect of its fault location [5]. The large-scale components oriented massive field

E-mail address: dingr@buaa.edu.cn, {lixiaoguang, zhutongyu, zhongzhenhan, zhangjufu}@nlsde.buaa.edu.cn

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measurement environment, especially when it need to take hundreds or even thousands measuring cables, and constitute multilink as well, can easily cause complicated and confusing working environment.

In this paper, we focus on the point of fault location and research on an intelligent method in distributed measurement environment. This paper is organized as follows: Section II briefly reviews the previous work and the limitation that is not resolved completely. And in Section III, system classification is given, and based on system classification, an intelligent fault location method is provided in Section IV. Then experiments are carried out and result evaluations are carried out in Section V. Finally, Section VI concludes the paper.

2. Related Work

In this section, we discuss the related work on fault location methods.

One mathematical model of fault location is proposed in [6]. Authors present a novel GIS fault location method in distribution network by algorithm of rough sets. Based on further researches of rough set theory, this fault algorithm simplifies the decision table of topological structure for distribution network, and finally considerably saves the time during fault location.

As concerns the fault location methods on large-scale mechanical equipments, the paper [7] shows common fault locations and points that the complex structure of mechanical equipment makes it difficult for fault location, the structure is composed of independent components, and enormous subsystems are contained in each part. To solve this problem, an improved genetic algorithm is developing in [8].

However, all the schemes or algorithms are suitable for small-scale measurement systems, may not be appropriate in large-scale ones, even in [8], it only discusses the condition of one single mechanical equipment. Therefore, we research on intelligent fault location algorithms in large-scale measurement system. At first, a system model is given and then different functional modules are classified in the system.

3. System Classification

In this section, firstly, a large-scale measurement system model is described, and secondly, the details of classification are proposed, and also advantages in the last part.

We assume a measurement system as is shown in Fig 1, several Measuring Sensors (MS) are connected with one Data Acquisition Module (DAM), and one Industrial Personal Computer (IPC) fetches the data from several DAMs which are related to IPC via Low-level field buses such as CAN or USB buses. Then several IPCs gain access to the network, and all real-time data messages packaged by IPC will be automatically dispatched by Switch in order that the background system operated on a Terminal Computer (TC) could assemble and process the data by the instruction. Meanwhile, the milieu of complex industrial field may cause malfunction easily if the system puts cable links to use while transmitting data especially from IPC to TC, thus, a redundancy module comes out into view. We introduce wireless Ethernet transmission mechanism into the architecture. However, instead of taking the place of cable links, it is suitable for wireless Ethernet as a backup link to ensure continuity of data transmission once the failure occurs on cable links, and further guarantee the robustness of the system.

By introducing the general idea of the architecture and model of large-scale measurement system in the previous part, the whole system can be classified as three independent functional units. They are Data Acquisition Unit (DAU), Data Transmission Unit (DTU) and TC.

As is shown in Fig 2, DAU contains three parts, MS, DAM and IPC. They together finish the data acquisition work, which is transforming electrical signals into analog quantity, and then digital quantity, and finally Ethernet message. DTU is implemented as a cascade of several multiplex switches. TC is a high-performance computer which can assemble messages, process the data and finally give a display figure and the results of analysis. Also, the redundancy wireless module is fixed on DAU, and an Access Point (AP) is installed on TC.

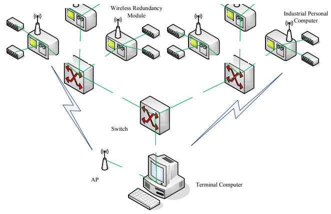


Fig. 1. The Architecture of Large-scale Measurement System

Fig. 2. The Structure of System Classification

After functional classification, different components complete one job together, and then, if once one malfunction happens, we can infer which level of the malfunction happens. Also we can deduce which fault happens on functional components according to the manifestations of fault, and thus it is helpful to the intelligent fault location.

4. Intelligent Fault Localization Method

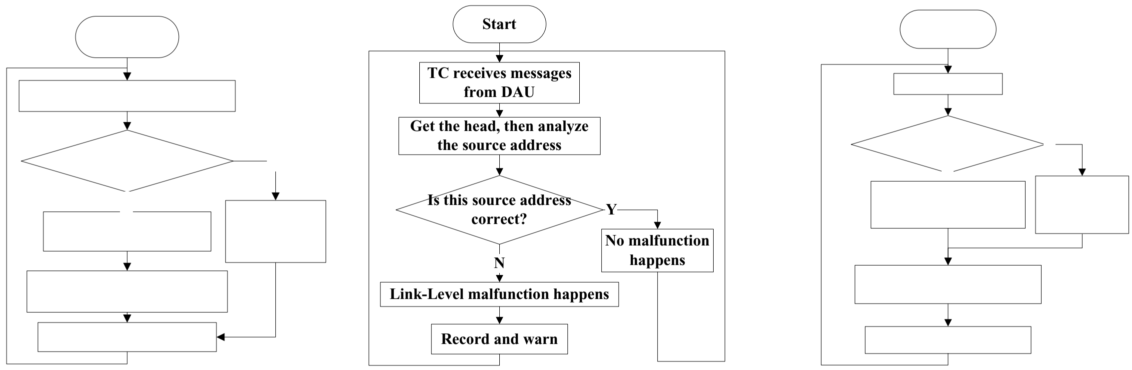
In this section, we put forward our novel approach — the method of intelligent fault localization — after challenge the question of how to embody intelligence in our algorithm.

It is an innovative idea to embody intelligence in fault localization field. The reasons of "intelligent" are shown as follows. Firstly, system can obtain the type of malfunction intelligently. Our method can ensure that a single fault whether happens on DAU or DTU. Secondly, accurate localization is based on the detection of fault type. Once the TC receives the fault type, TC can make a correct judgment that which DAU or which transmission link is broken down. Thirdly, after localization, system has an auto-recovery function and part of problems can be solved automatically.

As is discussed in Section 3, three different classifications: DAU, DTU and TC give fault localization a novel idea. Here we give three levels of fault localization: Node-Level, Module-Level and Link-Level.

Fig 3(a) shows the brief flowchart for Node-Level malfunction localization. On a certain measuring node, that is a measuring sensor, there are two major types of malfunction. One is the disconnection of circuit between MS and DAM. In this case, the data collected from the MS present a clear character of continuous limit, which is equivalent to open circuit. As soon as getting the abnormal data from MS, DAM collecting the node data will transfer the mistake data to IPC, and IPC preprocesses and analysis it, and then transfer the type of fault node and other information to the TC through the DTU.

As is shown in Fig 3(b), the brief flowchart for Module-Level malfunction localization is proposed. When malfunctions occur on some acquisition module, the data collected on the DAM cannot normally send to IPC, thus IPC cannot collect any data on the DAM. As a result of each acquisition module has an ID, IPC can get module information, and then, malfunctions of DAM information are transferred to TC through the DTU.



(a) Node-Level (b) Module-Level (c) Link-Level

Fig. 3. Brief Flowchart for Malfunction Localization

At last, we analyze Fig 3(c), which is the means of Link-Level malfunction localization. When one of the cable links is disconnected, IPC cannot send data messaged acquired and packaged to TC through the DTU. As is shown in Fig 2, redundant links are existed in our architecture, thus IPC can transfer data messages via redundant links. For the TC is concerned, Link-Level malfunction appears when it receives a redundant links data message on the basis of the analysis of the data, after that correctly identifies the line and fault type as well, and finally completes Link-Level fault location function.

5. Experiments and Result Evaluation

In this section, we introduce our experiments. Firstly we introduce the experimental platform for intelligent fault location, and then the detail of experiments will be described in the second part, and at the end of the second part, we give our analysis of experiments.

The Ethernet-based communication mechanism is adopted in the whole system. A three-layer framework that consists of DAU, DTU and TC is built, and wireless Ethernet transmission mechanism is introduce into the architecture as the redundancy transmission module. In DAU of our experimental platform, we use 120Ω stress sensor as MS, USB2810 high-speed AD converter of Art Technology Company as DAM and IGO-300C of ANOVO Technology Company as IPC. Each AD converter collects data from 32 stress sensors and each IPC can connect with at most four DAMs. Thus, one IPC can collect data from at most 256 stress sensors.

In order to validate the reliability of Node-Level fault localization, faults on some single MS is manufactured artificially. Firstly, the stress sensor is disconnected when the system is running normally. We examine whether the IPC can monitor the Node-Level malfunction, and immediately send messages carried fault information to TC, and whether TC can give corresponding tooltip messages of Node-Level malfunction or not. Then, we simply pull one DAM out of IPC to validate the reliability of Module-Level fault localization. We also examine whether the IPC can monitor the Module-Level malfunction, and immediately send messages carried fault information to TC. The last experiment is the examination on the reliability of Link-Level fault localization. We disable the data transmission device on IPC, and then, examine whether the redundancy transmission module can be in working order. Also, we examine whether the TC can monitor the Link-Level malfunction, and give corresponding tooltip messages of Link-Level malfunction or not.

Table 1. Accuracy of Fault Localization in Each Level

Level of Fault	Frequency of Fault Occurrence	Frequency of Fault Location	Accuracy
Node-Level	1000	1000	100%
Module-Level	1000	1000	100%
Link-Level	200	200	100%

Table 2. Average Delay Time of Fault Localization in Each Level

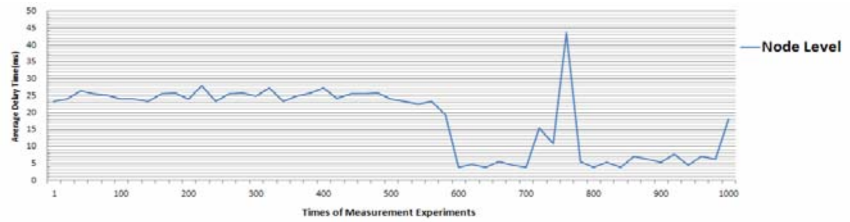
Level of Fault	Frequency of Successful Location	Average Delay Time (ms)
Node-Level	1000	18.092
Module-Level	1000	10.04
Link-Level	200	35.08

The results are shown in Fig 4 (a), (b) and (c), and consolidated measured data are shown in Table 1 and Table 2.As is shown in Table 1 and Table 2, the accuracy and average delay time of fault localization are given, and while adopting our intelligent fault location method, the rate of accuracy of Module-Level and Link-Level malfunction is 100 percent. And the average processing time is in the order of milliseconds. Therefore, we can clearly find that the excellent performance is revealed obviously in our experiments.

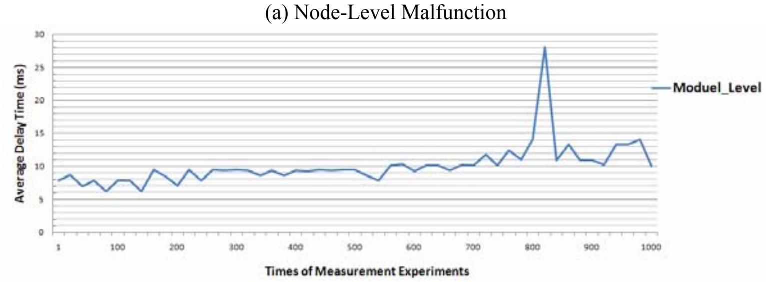
6. Conclusion and Future Work

In this paper, a new fault location approach for multistage in DMS, which first classify the measurement system, and then details of malfunction location algorithms corresponding to all levels are given. Our experimental results show that our algorithm can accurately and quickly achieve the mission.

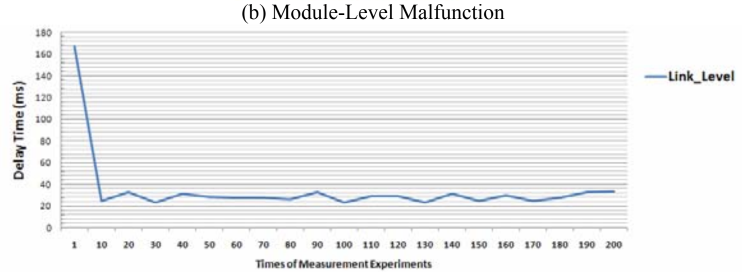
However, our current algorithm is not perfect in some cases. For example, we can detect and localize Link-Level malfunction correctly, but the processing delay time is a little long. Also, self repairing of malfunction is still a problem to be solved in future.



(a) Node-Level Malfunction



(b) Module-Level Malfunction



(c) Link-Level Malfunction

Fig.4. Delay Time of Fault Localization in Each Level

Acknowledgements

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References

[1] Barford L, Kanevsky V, Kamas L, Fault Diagnosis in Large-scale Measurement Systems, *IMTC 04*, Coma Italy,p.1234-1239.

[2] Jianping Yu, Wen Wang, Xinxin Li, Zhu Zhu, Zichen Chen, “Simulation Analysis on Characteristics of a Planar Capacitive Sensor for Large-Scale Measurement”, *ICICTA '09*, Zhangjiajie, China, 10-11 October, 2009, pp: 201-204.

[3] Xu Wei, CAN Protocol for Distribute Measurement System, *Journal of Control&Automation*,2007;23;11-2,p. 32-35.

[4] JIANG Ping, LU Guoqiang, FENG Qibin, Research on the multi-agent based distributed measurement system, *Journal of Hefei University of technology*,2006;29: 8.p. 1035-1038.

[5] Xing Yan, Wu Hongxin, Wang Xiaolei and Li Zhibin, Survey of Fault Diagnosis and Fault-tolerance Control Technology for Spacecraft, *Chinese Journal of Astronautics*, vol. 24, 2003, pp. 221-226.

[6] Tongyu Xu, Yingli Cao, Wei Zheng, Study of Fault Location by Algorithm of Rough Sets for Distribution Network, *International Conference on Sustainable Power Generation and Supply*, April. 6-7 2009, Nanjing, China ,pp: 1-4.

[7] Wang Lin, The Usual Methods of Fault Diagnosis and Monitoring for Mechanical Equipment and It’s Development Trend, *Journal of Wuhan University of Technology*, vol. 22, 2006, pp. 62-64.

[8] Huang Zhi-yong, Research on Fault Location of Large-scale Mechanical Equipment Based on Improved Genetic Algorithm, *MVHI 2010* ,April. 24-25 2010, Kaifeng, China, pp: 21-24.